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Final Technical Report for
the 3 DLE Instrument on ATS-5

(NASA-CR-132855) THE 3 DLE INSTRUMENT
ON ATS-5 Final Technical Report
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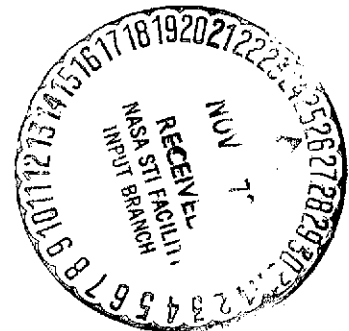
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1.0 Summary and Abstract

The UCSD plasma instrument on board ATS-5 has made significant contributions to the understanding of magnetospheric dynamics. During the lifetime of this contract the impressive list of talks and papers given in the appendix were prepared and given to an international audience of scientists.

A second class of contributions made by this instrument has been the partial understanding of the ubiquitous problem of spacecraft charging. Engineers have already used our results in designing other spacecraft such as the European synchronous scientific spacecraft GEOS.

Study of the data already taken is being continued with other funding (NASA Grant NGL 05-005-007). The emphasis is now on correlating data with other experimenters. We have a paper in press which gives results comparing plasma data with all-sky camera pictures. We are also actively cooperating with S³ and INJUN 5 experimenters. Recently JPL has awarded us a grant to study the data for charging effects with emphasis on spacecraft - ion beam interactions

Finally, the results from ATS-5 have been used to improve the design of another experiment to be flown on ATS-F.

2.0 Instrument

The instrument is described in detail in both the Handbook which has been distributed and in the ATS-5 EME Operations Manual published by Westinghouse. Therefore, only a brief description will be given here.

Four detectors are arranged in electron-proton pairs^s oriented parallel and perpendicular to the longitudinal axis of the ATS-5. Each detector consists of a cylindrical electrostatic analyser and a "C" type channel electron multiplier. Special grids are used to suppress secondary electrons and post-accelerate the analysed particles. The energy range sampled is 50 eV to 50 keV. Counts are accumulated for 260 ms and readout every 320 ms.

A variety of operating modes is made possible by seven commands. These select such options as double-stepping in energy for high time resolution or tracking a peak in the distribution by means of an on-board servo-loop. Some commands allot the available telemetry to different detectors. All commands have been used throughout the life of ATS-5 in an attempt to maximize the scientific return.

The 3 DLE instrument has performed remarkably well. It has always responded properly to ground commands, and has had no detectable logic or high voltage problems, in spite of the high density packing that was used. At the time of writing, the proton channels are still operating with full efficiency, and the electron channels are operating with somewhat less than 1/10 of the original count rate. We expect that the instrument will still be giving very useful data throughout 1974 when ATS-F is scheduled to be launched. If that is so, the scientific return from both instruments operating at synchronous simultaneously will be much greater than the value of either operating alone.

3.0 Data Presentation

The usefulness of any scientific instrument is severely compromised if one does not have an adequate way to display the output. From the beginning of this program, we have tried to emphasize presenting the data in a form that makes it readily accessible and understandable to other workers so that they need not be intimately familiar with the instrument in order to use the data. We have tried to avoid generating large volumes of tabular hardcopy. Our normal data presentation consists of two parts:

3.1 Microfilm Line Plots

The raw data is plotted with about 80 sec (16 sequences) per graph. In the most commonly used operating mode, this represents four complete energy scans. No editing or efficiency correction is done at this stage. This format is best for looking at rapid fluctuations or isolated events (such as the 3-minute period on March 8, 1970 when we saw unshocked solar wind). We produced a library of two years worth of film before budgetary considerations forced us to eliminate the line plots from our standard reduction program. For the last year, we have produced them only for special events such as the August 4-5, 1972 geomagnetic storm, or on special request as when Canadian scientists launched a series of rockets from Ft. Churchill and Gillam. They wanted our data taken simultaneously, and we have been able to cooperate with them.

3.2 Spectrograms

After securing the initial data, we realized that many of the processes we were interested in required watching the development of the complete spectrum over a period of hours or even days. Since the line plot presentation is best suited for much shorter time intervals, Prof. Carl McIlwain developed the spectrogram routine which has continued to be the most generally used form of data presentation. (See the Plasma Clouds paper referenced in the Appendix). The essential feature of the spectrogram is that a whole day's worth of data can be displayed for an electron proton pair on one $8\frac{1}{2} \times 11$ photograph. The axes are energy and time while a grey scale is modulated by the counting rate. Time resolution is about 2.4 minutes for the normal spectrograms.

We have an almost complete library of spectrograms from September 1969 to January 1973. However, we were forced to change the format to two days per spectrogram in 1972 as an economy move. We feel that it is important to be able at least to see the data in some form, and two-day spectrograms are preferable to have some data not reduced at all.

In addition to presenting data efficiently, the spectrograms have developed into an important tool for analysing magnetospheric events. For instance, the timing of injection events even when ATS-5 is a long way from the injection site is relatively simple with spectrograms. For this and other reasons, many other investigators have requested copies of special days, and we have done our best to honor such requests.

At the same time the spectrograms are produced, average data tapes are made which contain the same information in easily read format. Also certain integrals such as pressure and density are printed out. This printout is

the only hardcopy normally produced. It is also available to other experimenters.

We are currently trying to produce a single reel of 35 mm film with all of our spectrograms on it. This reel could easily be duplicated and sent to other interested people.

4.0 Studies

The end product of a well designed instrument and efficient data presentation is the science that comes from the study. 3 DLE data has been used for a variety of studies, and will undoubtedly continue to be studied for a number of years since anyone familiar with it agrees that we have only scratched the surface in our analyses to date.

4.1 Plasma Dynamics

Both C. E. McIlwain and S. E. DeForest have been interested in the overall geometry of the magnetosphere and the dynamics of substorm injection. In addition, McIlwain has used the particle trajectories with a magnetic field configuration to infer the nature of electric fields in the vicinity of synchronous orbit. These results have been published, and more detailed studies are underway.

4.2 Flows

The unexpected spinning of ATS-5 has enabled us to use the perpendicular set of detectors to measure the component of plasma flow velocity perpendicular to the spin axis. Although the instrument had not been designed for these flow measurements, and the spin rate was much too fast, we are still able to despin the data and make reliable measurements of flows from several hundreds of kilometers per second down to about thirty kilometers per second. This

range allows us to investigate flows associated with substorm injection, magnetopause crossings, and Pc5 oscillations. Several talks have been given on these subjects, and a paper on magnetopause crossings is now in preparation.

A related type of study is possible using data from a one-week period early in the life of the spacecraft when the spin axis was in the equatorial plane. By despinning the data in the same manner as above, pitch angle distributions can be measured. Both pancake and field-aligned fluxes have been seen this way.

These observations have been the best source for design material for our ATS-F instrument.

4.3 Electrostatic Charging

Several papers have been presented showing aspects of charging phenomena on board ATS-5. The whole spacecraft charges up to thousands of volts (12,000 maximum to date) at certain times of the year, and parts of it charge up to thousands of volts routinely. These observations and the model that was developed to help explain them have been used to explain certain failures of other spacecraft including "anomolous changes of state" in certain Air Force spacecraft. We have also cooperated with JPL to predict charging effects in the vicinity of Jupiter.

Since we published our results on charging, at least 30 other spacecraft have been shown to have their operation affected in some way by electrostatic potentials developed on board. This important phenomena is currently being studied under the sponsorship of JPL with special emphasis on ion-beam spacecraft interactions.

4.4 Wave-Particle Interactions

The whole field of plasma wave-particle interactions has received much study not only for space problems, but also for plasma containment devices. Therefore, it was fitting that the first paper on this topic to be based on ATS-5 plasma data appeared in the journal "Physics of Fluids" (see reference by R. LaQuey in Appendix) instead of a purely geophysical journal. This paper dealt with electro-static drift waves seen commonly in ATS-5 with periods of several minutes.

A graduate student, D. Baxter, is currently finishing his Ph.D. thesis based on similar studies of plasma waves in this data.

Other types of waves have been observed in the data, but have not been studied in detail yet. A complete survey of plasma oscillation is a high priority item on the 3 DLE "things to do" list.

4.5 Correlative Studies

Most workers in magnetospheric research recognize that further advances will require coordinated studies using instruments at different locations taking simultaneous data. We have long had the policy of exchanging data with other experimenters and trying to do correlative studies. Currently, we have a paper in press giving results of comparison of ATS-5 data with ground-based all-sky camera pictures from the Great Whale River station. We are also actively cooperating with the S³ experimenters at both NOAA and GSFC. During the last year we have carried on active correspondence with the German group which is running the INJUN 5 satellite.

Arnoldy and Choy of New Hampshire have published a paper comparing our data with a rocket flight they made from Fort Churchill, and we have exchanged data with a Canadian group that launched simultaneous rockets for Ft. Churchill and Gillam.

4.6 Things Left To Do

As mentioned earlier, the ATS-5 data is still being analyzed and we feel that we have only scratched the surface of possible scientific findings in the data. The total list of things that we want to do is quite formidable, but it can be summarized in six broad categories:

1. Electric fields,
2. Flows,
3. Wave particle interactions,
4. Magnetospheric geometry,
5. Charging problem, and
6. Correlative studies.

In particular, for number 6, we hope to get some overlap data between ATS-5 and ATS-F.

5.0 APPENDIX

Publications and presentations generated by the UCSD plasma instrument on board ATS-5 are as follows:

- Akasofu, S. E., S. E. DeForest, and C. E. McIlwain, "Correlation between ATS-5 plasma data and all-sky auroral photographs" submitted to Planetary and Space Science, 1973.
- Archuleta, R. J., and S. E. DeForest, "Efficiency of Channel Electron Multipliers for Electrons of 1-50 Kev, Review of Scientific Instruments, January 1971.
- Baxter, D. C., and R. E. LaQuey, "Plasma Waves at 2-3 millihertz Observed at 6.6 Earth Radii," Trans. American Geophysical Union, 54, 426, April 1973 (Abstract). Presented at AGU Spring Meeting, Washington, D.C., April 1973, and to be published in J. Geophys. Res.
- DeForest, S. E., and R. J. Walker, "Use of Electronic Computers to Aid in the Design of Satellite borne Experiments, UCSD-SP-27-3, UCSD, La Jolla, California, June 1967.
- DeForest, S. E., "Initial Results of ATS-5 Plasma Experiment," Trans. American Geophysical Union, 50, 11, Nov. 1969 (Abstract). Presented at American Geophysical Union Winter Meeting, San Francisco, December 1969.
- DeForest, S. E., "Precipices and Chasms in the Magnetospheric Plasma", Trans. American Geophysical Union, 51, 4, Apr. 1970 (Abstract). Presented at American Geophysical Union Spring Meeting, Washington, D.C., April 1970; and at International Symposium on Solar Terrestrial Physics (URSI/COSPAR) Leningrad, Russia (1970).
- DeForest, S. E., and C. E. McIlwain, "Plasma Clouds in the Magnetosphere", J. Geophys. Res., 76, 3587, June 1971.
- DeForest, S. E., "Plasma Flows at Synchronous Orbit" invited presentation at Section III URSI Meeting, UCLA, September 1971.
- DeForest, S. E., "Spacecraft Charging at Synchronous Orbit," J. Geophys. Res., 77, 651, February 1972.
- DeForest, S. E., "Electrostatic Potentials Developed by ATS-5," talk given at the Sixth Eslab Symposium, "Photon and Particle Interaction with Surfaces in Space" at Noordwijk, Netherlands, Sept. 1972, and published in the Proceedings, D. Reidel Pub. Co., Dordrecht, Netherlands.